

PROTECTING SOLDIERS: WARNING PRESENTATION AND RETENTION UNDER STRESS IN A VIRTUAL MILITARY TASK

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ABSTRACT

In the modern combat environment, information superiority and superior information systems are paramount to operational success. Considerable efforts are applied to task gathering, collating, synthesizing, and conveying this vital information. The same level of energy must be brought to bear in devising innovative and effective methods for communicating this information to the soldier. The modality in which the warning information is presented is imperative in this process in that it differentially influences behavioral response, especially when tasks are either learned or subsequently performed in stressful circumstances. The current work examines the effects of cross modality of warning presentation and retention in a dual task paradigm in a simulated environment with various task-induced stress levels. Consistent with the Hancock and Warm model of stress and attention, it was found that when task demand is relatively low, the modality of presentation is of less importance and participants are able to comply. When task demand is relatively high, the modality of presentation was critical and played a significant role in compliance behavior. Additionally, it was found that participants were significantly less likely to comply in the verbal modality across all levels of working memory demand than in either the pictorial or written modalities.

1. INTRODUCTION

The donning of protective gear is invaluable when protecting soldiers from severe injuries and even death in combat. For example, the results of a study including 118 Army troops which were evacuated from Iraq with severe battlefield injuries yielded 73 percent of the injuries were to the hands, feet arms, and legs with only 9 percent of the injuries incurred to the abdomen, chest, back, or groin (Brown, 2003). All of these soldiers were wearing body armor at the time the injuries were incurred, thus, wearing the protective gear decreased the number of severe

and fatal injuries which may have occurred if the body armor was not worn. Consequently, protective gear can only protect the soldier that dons the gear. Recently, body armor has been technologically improved increasing its effectiveness when worn. Recent improvements with body armor include reducing the weight of the gear, yet for ground troops the gear may still be a fatiguing load to wear causing the soldier to remove the body armor. Although it is not always necessary for soldiers to wear all of their protective equipment, such as the protective mask, it is crucial to communicate warnings effectively for soldiers to be warned when a hazardous situation arises and what action to take to protect themselves, such as donning the appropriate protective equipment.

Another aspect that must be considered in communicating warnings effectively is that warnings are usually not presented in isolation, but are generally presented while the soldier is performing a certain operational task and often under stressful conditions. Thus, warning messages must attract the soldiers' attention, inform them of the hazard, and convince them to comply. The format in which warnings is presented is not standardized; warnings vary in their presentation format across tasks and environments. Presentations of hazard warnings are commonly found in one of the following formats: pictorial, written, or auditory. Consequently, the literature pertaining to format is unclear as to which types of presentation is most memorable, salient, or most effective resulting in a higher rate of compliance behavior under stressful conditions (Ells & Dewar, 1979; Glenberg & Langston, 1992; Janda & Volk 1934; Larkin & Simon, 1987; Paivo, Rogers, & Smythe, 1968; Penney, 1975; Standing, Conezio, & Haber, 1970).

In the current study, we manipulated warning presentation and warning retention in a dual task paradigm. Presentation was manipulated by the format of presentation of the warning cues (verbal, written or pictorial). In order to determine

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which type of presentation is most effective, we measured retention performance by calculating which format had the highest recall rate. Retention performance of the learned associations between the hazard and the warning cue was measured by the number of correctly recalled associations while simultaneously interacting with the simulated military task. Furthermore, in accordance with the Wickens' multiple resource theory (Wickens, 1984; Wickens, Sandry, & Vidulich, 1983), it was hypothesized that warnings presented in verbal compared to written and pictorial formats would result in significantly higher rate of compliance behavior since the simulated military task in this study is predominantly a visual and spatial task.

Clearly, format of presentation is an important factor leading to compliance behavior; however, compliance behavior may also be affected by stress. An experiment conducted by Magurno and Wogalter (1994) concluded that participants under low stress conditions were more likely to comply with warnings than under high stress conditions. Thus, these results are in accordance with the Hancock and Warm model (1989). This model predicts that performance will be affected by stress when it increases to the point that it is outside of the comfort zone. In the current study, operational stress level was manipulated by the task demands of the warning-compliance task (the number of association cues that the participant had to retrieve). In particular, it was of interest to determine the amount of task demand which still provides a high level of compliance. Therefore, it was hypothesized that the comfort zone would be maintained when a participant was presented with a maximum of four stimuli in any format. Furthermore, when participants were presented with more than four stimuli they would fall outside of the comfort zone resulting in degraded performance.

Compliance to warning information may also be affected by individual differences in working memory capacity. If an individual does not have the resources to support the amount or type of warning information that is to be stored or processed, then they may not be capable of heeding the warning. Many theorists support the notion of separability of working memory resources for spatial thinking and language comprehension (Daneman & Carpenter, 1980; Daneman & Tardif, 1987; Shah and Miyake, 1996). In accordance with the separability of working memory theory, this experiment seeks to

determine whether warning presentation is contingent upon individual differences in available capacity and processing resources in verbal and spatial working memory. It is hypothesized that the processing and storage capacity will determine an individual's ability to comply with warnings presented in the different modalities.

2. METHOD

2.1 Participants

Twenty-two (mean age = 21.2, $SD = 3.4$) participants were recruited on a voluntary basis from undergraduate psychology classes at the University of Central Florida and were paid approximately \$37.50 for their participation (based on an hourly rate of \$7.50).

2.2 Materials

Dual Task Setting. The Warning Color-Combination (WCCOM) compliance task and the shooting task were presented on two separate monitors with two keyboards and mice. The computer used for the WCCOM had two speakers which were used to present the verbal warnings. The computer used for the shooting task did not have speakers, thus no noise was emitted from during the task. The two computers were placed on a desk side-by-side in order for participants to easily view both monitors.

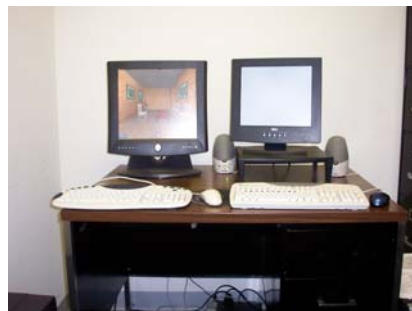


Figure 1. This picture depicts the experimental set up with both monitors, keyboards, mice, and speakers.

WCCOM Compliance Task. WCCOM was one of the two tasks in the dual task paradigm. The warning-color combinations in this task consisted of one of ten warnings (boots, earmuffs, glasses, gloves, helmet, shield, suit, respirator, meter, or mask) paired with one of ten colors (red, blue, green, orange, purple, black, white, gray, brown, or yellow; recommended by the American

National Standards Institute, Inc.; ANSI, 1991). The WCCOM consisted of both a storage and a processing requirement. The storage requirement consisted of learning the color associated with each warning. Warnings were presented in one of three modalities, pictorial, written, or verbal. Each combination was paired randomly and appeared only once per block.

Each warning-color combination was presented individually on the computer screen for five seconds. An example of the pictorial presentation of the WCCOM is depicted in Figure 1. In this example the warning, boots, is paired with the color black. The written warnings were presented in the same manner (see Figure 2). The verbal WCCOM was presented via speakers. For example, the participants heard “boots...black”. Operational stress level was manipulated by the working memory demands of the WCCOM, the number of association cues that the operator had to retrieve, which increased in demand from two to four to eight.

The processing requirement of the task involved complying with the warning (responding with a keypress) while simultaneously performing the shooting task. Each trial consisted of a two-minute session of the shooting task during which the color portion of the WCCOM was presented at random times. The participant’s task was to remember the correct pairing of the warning and color combinations. They responded by pressing the appropriately labeled key on a second keyboard with their right hand.



Figure 1. Example of a pictorial warning-color combination (left) and the color stimulus (right) that elicits the key press response during the WCCOM portion of the dual task. In this specific example, the warning, boots, are combined with the color black.



Figure 2. Example of a written warning-color combination (left) and the color stimulus (right) that elicits the key press response during the WCCOM portion of the dual task.

Shooting Task. During each trial, the participants completed a two-minute mission in Ghost Recon. During each mission, the objective was to clear a building by entering each room and killing all of the enemies. Participants navigated through the Ghost Recon environment using the arrow keys on one keyboard with their left hand and the mouse with their right hand. Performance was measured by calculating the hit percentage (number of shots which hit a target divided by the total number of shots fired).

Working Memory Tasks. Four working memory tasks were used in order to predict the processing and storage capacity of working memory. In order to test for spatial working memory capacity both verification arrow task and the spatial span were administered. Likewise, to test for verbal working memory capacity both the verification word task and the reading span were administered (see Shah and Miyake, 1996).

Card Sorting Task. One complete deck of playing cards was used to administer the card sorting task. This task was used as an attempt to diminish carry over effects from the previous trial.

2.3 Procedure

A mixed model design was used which included three within subject variables that were presentation type (verbal, written, and pictorial), trial (1-5), and working memory demand (2, 4, and 8). The between subject variable was the response method used (written or pictorial). The experimental procedure consisted of three blocks (one for each modality: verbal, written, and pictorial); each block consisted of 15 trials (5 repetitions for each task demand level at 2, 4, and 8 warnings). Presentation order of the modality conditions was counterbalanced between blocks to avoid the effect of sequencing. Additionally, the presentation order of trials within each block was randomized.

Testing occurred in two sessions (approximately 2.5 hours each) on different days during a one week period. During Session 1 participants were asked to complete the informed consent, demographic questionnaire, and the State-Trait Anxiety Inventory (STAI). After a five-minute break, the working memory tasks were administered followed by another five-minute break. The participants completed a practice session, which consisted of three trials of the Ghost Recon task, the WCCOM, and both

tasks simultaneously (dual task setting). The participant's task was to remember the correct pairing of the warning and color combinations. The experimental task required the participants to first store the WCCOM (2, 4 or 8 combinations depending on the level of task demand), followed by the processing portion of the task. The processing portion of the task involved complying with the warning stimulus (presented as colors) while simultaneously performing the Ghost Recon task. When participants either saw or heard (depending on the modality of presentation in that block) the warning, they responded by pressing the appropriately labeled key on a second keyboard (keys 'q' through 'p' are labeled with the warning portion of each combination which was either in written or pictorial format) with their right hand. Following the practice sessions, participants completed the first block. Session 2 consisted of the remaining two blocks of the experiment. A five-minute break was scheduled between blocks.

During both sessions, the Rating Scale Mental Effort (RSME; Zijlstra, & Van Doorn, 1985) and the card-sorting task were administered following each trial and the NASA-Task Load Index (NASA-TLX; Hart, & Staveland, 1988) follows each block. Finally, participants were debriefed via a verbal and written statement.

4. RESULTS

Prior to all analyses, eleven missing cases were replaced with averages.

WCCOM Task. A three-way 3 (modality) X 3 (task demand) X 5 (trial) X 2 (response type) repeated measure analysis of variance (ANOVA) was conducted on warning compliance behavior. The within subjects variables were modality, task demand, and trial. The between subject variable was response type. Analyses were performed using SPSS, for Windows, 11.0 and an alpha level of .05 was used.

There was a significant main effect of modality and task demand, Wilk's $\Lambda = .303$, $F(2, 19) = 21.9$, $p < .0005$, partial $\eta^2 = .70$, and Wilk's $\Lambda = .50$, $F(2, 19) = 9.4$, $p < .0005$, partial $\eta^2 = .50$, respectively. No main effects for response type or trial were found.

A set of Fisher LSD post hoc tests for modality type show that participants were significantly more likely to comply when the

information was presented in the written, ($M = 67$, $SD = 3$) than in pictorial ($M = 56$, $SD = 3$) or verbal modality ($M = 54$, $SD = 3$).

Three two-way interactions were found. The first interaction was between modality and response type $F(2,19) = 11.4$, $p < .0005$, the second between task demand and response type $F(2,19) = 63.3$, $p < .0005$, and the third between task demand and trial $F(8,13) = 1.03$, $p < .0005$. Since response type did not yield a main effect the interactions may be due to the robust findings for the effects of modality and working memory. Although no trends are found, differences do seem to emerge between verbal presentation of warnings with pictorial response mode and verbal warning with written responses. Furthermore, no consistent trends can be seen from the response mode and task demand. Further investigations must be done in order to get a clear understanding of these interactions.

Workload. A three-way 3 (modality) X 3 (task demand) X 5 (trial) X 2 (response type) repeated measure analysis of variance (ANOVA) was conducted on RSME workload scores. The within subjects variables were modality, task demand, and trial. The between subject variable was response type. Analyses were performed using SPSS, for Windows, 11.0 and an alpha level of .05 was used.

There was a significant main effect of modality and task demand, Wilk's $\Lambda = .58$, $F(2, 19) = 6.98$, $p = .005$, partial $\eta^2 = .42$, and Wilk's $\Lambda = .64$, $F(2, 19) = 16.9$, $p < .0005$, partial $\eta^2 = .64$, respectively. No main effects for response type or trial were found. A set of Fisher LSD post hoc tests for modality type show that participants were significantly less loaded when the information was presented in the written, ($M = 44$, $SD = 3$) than in pictorial ($M = 52$, $SD = 4$) or verbal modality ($M = 53$, $SD = 3$). Furthermore, Fisher LSD post hoc tests for working memory show that participants were significantly more loaded at level two ($M = 36$, $SD = 3$) than at level four ($M = 49$, $SD = 3$) and eight ($M = 61$, $SD = 4$), as well as between levels of four and eight.

Two two-way interactions were found. The first interaction was between task demand and response type $F(4,17) = 6.55$, $p = .007$, and between response and trial $F(4,17) = 6.27$, $p = .003$. As seen in the WCCOM task, response did not yield a main effect, the interaction between task demands and response mode may be due to

the robustness of the main effects of task demand because no other trends are emerging. The interaction between trial and response has a trending toward having lower workload measures when the response mode is in written format.

NASA-TLX scores are currently being analyzed.

Ghost Recon Shooting Task. A three-way 3 (modality) X 3 (task demand) X 5 (trial) within-participants repeated measure analysis of variance (ANOVA) was conducted on percentage of enemies killed compared to the number of enemies in that mission. Analyses were performed using SPSS, for Windows, 11.0 and an alpha level of .05 was used.

There were no significant main effects or interactions.

Individual differences in Working Memory Tasks. Data collection is ongoing; a larger sample size is needed in order to analyze the data.

5. Conclusion

The results of this study are relevant in securing the safety of soldiers. As historical research has proven the donning of protective gear is necessary in order to protect soldiers from severe injuries and even death in combat. The study identified the best format and task demand to present warning effectively to increase the likelihood of soldiers wearing protective gear. Results of this experiment indicate that participants presented with warnings in written or pictorial format complied significantly more than when presented with verbal warnings regardless of response mode. In addition this mode of presentation generated the least workload on operators. Consistent with the Hancock and Warm model of stress and attention (Hancock & Warm, 1989), comfort zone was maintained when a maximum of four stimuli in any format of presentation. Furthermore, when eight stimuli were presented, retention degraded. Thus, when task demands (task stress) are relatively low (two and four warning stimuli), the format of presentation is of less importance and participants are able to comply. When task demands are relatively high (eight warnings) the format of presentation was important and played a significant role in compliance behavior.

In addition to the decrease in compliance scores when task demands increased, perceived

workload increased. Participants felt that they had to use more of their mental resources as the level of task demand increased from level two to four to eight.

The implication that this has on the modern day soldier is critical to their survival. With the increase of information presented to soldiers, they are often presented with critical warning information while simultaneously performing some other task or receiving other important information. The warning message must be salient, and stand out from other environmental distractions. Thus, when task demand is high, the presentation format of warning information needs to be considered.

Future research in this area will first determine whether warning presentation is contingent upon individual differences in working memory storage and processing capacity. In this current line of research a continuation of collecting data on individual differences will continue. Secondly, the current study only investigated the differences between pictorial and written response modes on the WCCOM task, in the future a verbal response mode will be implemented and compared. Thirdly, the Ghost Recon shooting task will be replace for a Ghost Recon navigation task in order to see results of this study can be replicated if a more difficult task is implemented into the dual task paradigm.

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